Stratospheric Observatory for Infrared Astronomy SOFIA

Listening to Light — Teacher Notes

5.1 WHAT'S THIS ABOUT?

Students learn that light carries information and that infrared (IR) radiation is a form of light that in some cases behaves like visible light and other cases behaves very differently. Students first see how a photocell (solar cell) can be used to detect the presence of light. They then learn how the photocell reacts to light from a laser pointer (or other laser) and a remote control, and see that information, for example a message, can be transmitted by visible and infrared light. They listen as an infrared-emitting diode is used to transmit music from an audio source (like a CD player) to the photocell with a speaker connected to it. Finally, students test the effects on the transmission of music when various objects are placed in between the infrared-emitting diode and the photocell. They learn that some objects that block visible light allow infrared light to pass through.

Grade Levels
7-12

Time Required
50-100 minutes, 1 to 2 class periods

Learning Objectives
After completing this activity, students will be able to:
- Describe different characteristics of visible and infrared light observed using a photocell as a detector.
- Explain how information can be carried by visible and infrared light.
- Predict whether visible or infrared light will be transmitted through various objects.

Student Prerequisites and Misconceptions
- Students are assumed to be familiar with visible light and infrared light, and that both are part of the electromagnetic spectrum. For an introduction to the electromagnetic spectrum, see: http://imagers.gsfc.nasa.gov/ems/ems.html
- This activity assumes some familiarity assembling and working with electronic circuits, magnifying glass lenses, laser light, and remote controls.
- Common misconceptions are described in the overview for these activities, "Active Astronomy : Classroom Activities for Learning about Infrared Light," page 3.

BACKGROUND INFORMATION ON THE SCIENCE & TECHNOLOGY

In this lecture demonstration, an infrared light-emitting diode (LED) is used to transmit music across open space to a speaker. The music can come from a Walkman, stereo, CD player, computer, amplified microphone, or any similar device. The transmitter circuit contains an infrared Light Emitting Diode (LED) whose brightness varies in response to changes in input current. The receiver circuit uses a photocell to detect the IR signal and convert it back to an electrical signal for the speaker. The student activity sheets call the receiver circuit the "photocell detector."

After showing the basic operation of this demonstration, the equipment can be used to investigate some basic properties of the infrared light coming from the diode. First, and most obvious, is that the IR light is invisible. Second, a magnifying glass can be used to show that infrared signal is focused the same as visible light. (Note: Glass is not transparent to all infrared light. It is transparent to near-infrared light—wavelengths close to visible light. The LED used in this activity emits near-infrared light. Glass is opaque, however, to infrared light with longer wavelengths.) Finally, different materials are placed between the diode and the photocell to show that the IR light can pass through many materials that visible light cannot.

> SOFIA SCIENCE
> *Long light waves ranging from 03 to 1600 micrometers are normally invisible to human eyes. SOFIA's electronic detectors and computers will covert light gathered by the telescope into signals that humans can understand.*

Light-Emitting Diodes (LEDs) can be thought of as tiny light bulbs. (Note: A diode is a silicon crystal (semiconductor) that allows current to flow in one direction only, kind of like a one-way turnstile for electrons.) When a current is applied to an LED, electrons in the semiconductor material emit light. Because of the composition of the material in the LED used in this activity (usually a silicon compound), it emits infrared light, not visible light. The higher the incoming current, the more light the LED will emit. If the electrical signal coming into the LED is not strong enough, however, it will not emit any light. The battery and capacitor in the transmitter circuit provide a constant source of current that keeps the LED above this threshold, so it emits at least a constant amount of light, regardless of the incoming audio signal. Since the receiver circuit does not produce any sound when exposed to a constant light source, the constant light from the LED caused by the battery and capacitor is not detected. Instead, the receiver circuit detects changes in the brightness of light emitted by the LED, changes that are caused by fluctuations in the incoming current from the audio source that are added on top of the battery's constant one.

Solar/Photo Cells: The solar cell used in this activity is known as a photovoltaic cell because it converts light (photo) into electricity (voltaic). When visible or infrared light strikes the solar cell, some of it is absorbed by the special material (usually silicon), called a semiconductor, out of which it is made. The energy of the absorbed light is transferred to the semiconductor material, knocking electrons in it loose. These loose electrons can then move freely throughout the material, resulting in an electric current. Most solar cells also have one or more electric fields in them which force the moving electrons to flow in one direction. By placing metal contacts at the top and bottom of the solar cell, the current flowing within it can be drawn off for use externally. In the case of this activity, the current generated by the light is sent to the amplifier/speaker, where it is converted into sound waves, which we can hear. For more detailed information about how a solar cell works, see: http://www.howstuffworks.com/solar-cell.htm

Audio Speakers: Inside a speaker, a flexible cone (usually made of paper, plastic, or metal) vibrates rapidly in response to a changing electrical current. As it moves, it pushes the air molecules around it. Those air molecules, in turn, push the air molecules near them, and the vibration is transmitted through the air as a sound wave. Our ears detect the vibration of air molecules and convert them into an electrical signal that our brain interprets as music. Within the speaker, the flexible cone needs a changing current to vibrate. If the current is constant, the cone will not vibrate. For more information on how speakers work, see: http://www.howstuffworks.com/speaker.htm

Remote Controls: When you press the button of a remote control, an electrical connection is made that tells a computer chip inside the remote which button was pressed. The chip then produces a morse-code-like electrical signal that is different and distinct for each button. Transistors inside the remote control amplify the signal and send it to a Light-Emitting Diode, or LED, a kind of small light bulb. The LED converts the electrical signal into infrared light. Because the LED emits infrared light, which our eyes cannot detect, we do not see any light passing between the remote control and the TV (or VCR). But, the TV (or VCR) has a detector which can see infrared light. Depending on the exact nature of the signal (its wavelength, frequency, or intensity), the TV (or VCR) carries out the desired command. *Note that many camcorders can also detect infrared light. If you aim a remote control at a camcorder and push a button, you should see infrared light flashing in the viewfinder.* For more information about how remote controls work, see: http://www.howthingswork.com/inside-rc.htm

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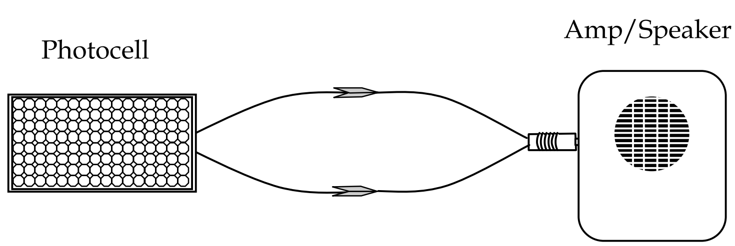
BUILDING THE DEMONSTRATION APARATUS

This lesson is described in the demonstration format based on the assumption that you will have only one apparatus available. Students in small groups can also build this apparatus if sufficient hardware is purchased.

<u>The Receiver Circuit: How It Works</u>

In this circuit, the photocell receives the IR signal from the LED and converts it to an electrical signal that is sent to the amplifier-speaker. This circuit is also used in another activity, "Sensing the Invisible."



The photocell (or solar cell), connected as shown above, produces an electric current when exposed to light. Because of the way speakers are constructed, a changing current is needed to produce a sound in the speaker; a constant current will not produce a sound. When a constant light source illuminates the photocell, it produces a constant current and no sound is produced. Students should hear static, if anything, when a constant light source illuminates the photocell. When the light changes in brightness, the current produced by the photocell also changes accordingly, and the speaker will produce a sound. If the light is turned on and off (as happens if you move your hand back and forth in the beam of light), you will hear series of “pops” each time the light is turned back on. If the light varies because of a changing electrical current from an audio source, you will hear music from the speaker.

NOTE: For best results, turn off any overhead fluorescent lights in the classroom. When the photocell is exposed to the fluorescent overhead lights, the speaker will emit a constant buzzing sound or hum. This buzzing occurs because the intensity of the classroom light fluctuates due to the 60 Hz AC current it receives. Thus, fluorescent lights will generate a constant hum, which may interfere with students’ hearing sound produced from the flashlight and the infrared diode in the transmitter circuit.

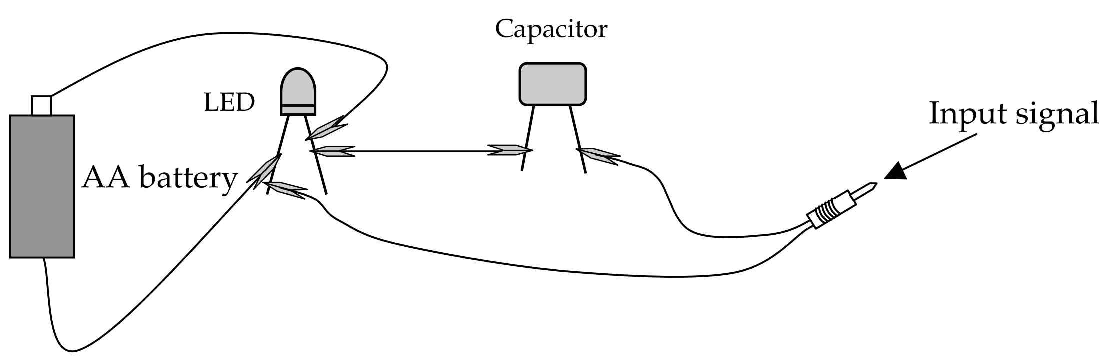
How to Build the Receiver Circuit:

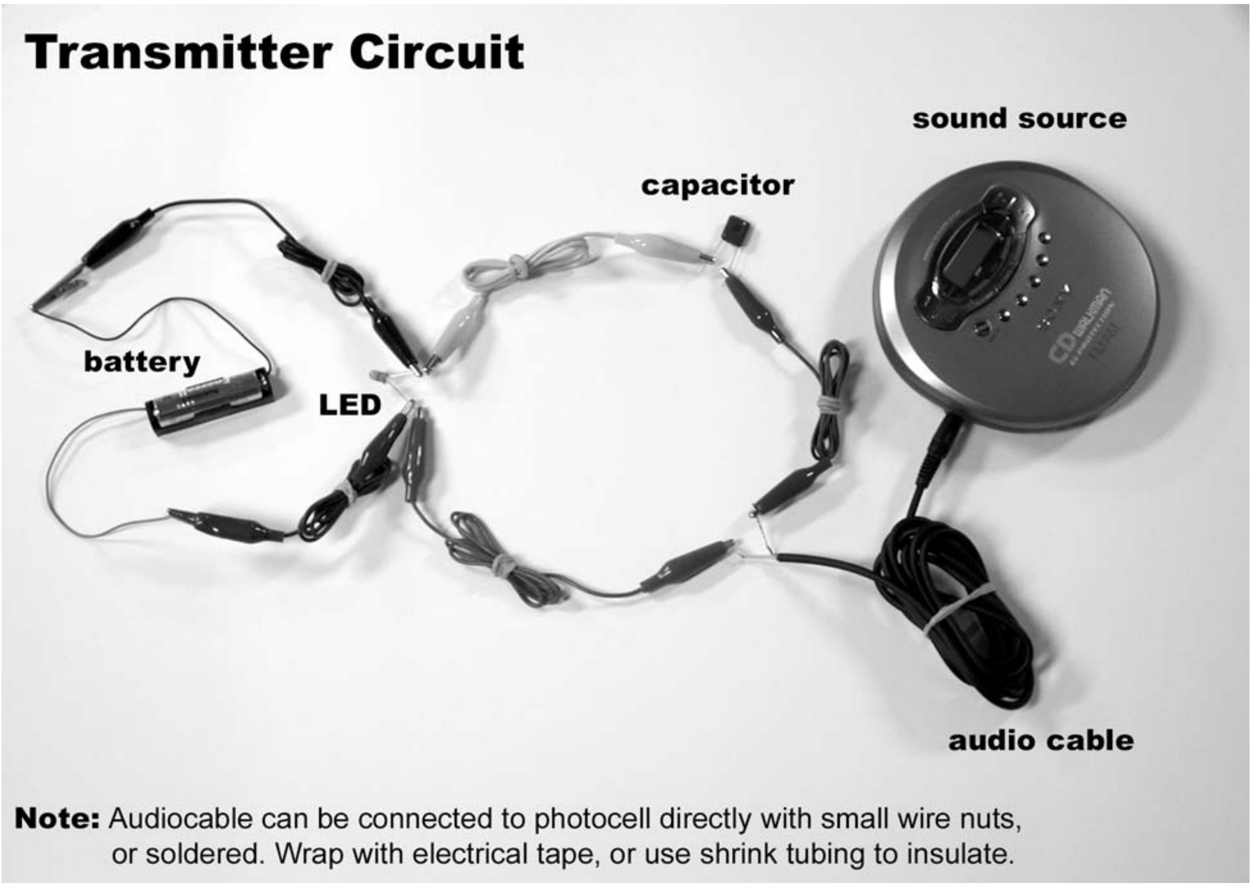
To make the photocell detector, use jumper cables to connect the photocell with the amplifier/speaker (amplifier/speaker requires a 9V battery). Clip one alligator clip from a jumper cable to one of the leads from the photocell, and clip the alligator clip at the other end of the jumper cable to one of the leads of the audio cable (which has its 1/8" mini-plug plugged into the "input" of the amp/speaker). Use a second jumper cable to connect the other lead from the photocell to the other lead of the audio cable.

This works best if you use an audio cable with a mini-plug on one end, and two exposed wire leads on the other. You can also use an audio cable with a mini-plug on both ends. In this case, connect the alligator clip from one jumper cable near the end of the mini-plug, and connect the alligator clip from the other jumper cable near the base of the mini-plug (next to the plastic piece that protects the rest of the audio cable). Be sure both alligator clips are in contact with metal parts of the mini-plug, and that they do not touch one another. Note that a Y-Adaptor Audio Cable will not work in this activity.

How to Build the The Transmitter Circuit

This circuit takes the output audio signal from an audio source (CD player, transistor radio, stereo, etc.), in the form of a changing electrical current, and sends it to the infrared light-emitting diode (LED). The LED converts the current into infrared light, in much the same way a regular light bulb "shines" when the light switch is turned on.





To make the transmitter circuit, use jumper cables to connect the LED to the battery, capacitor, and to the audio cable coming out of the audio source (CD player, transistor radio, etc.), as shown in the diagram above. Be sure to connect the audio cable to the Line Out jack of the audio source (like a Walkman), (or the Headphone jack if the Line Out is note effective). Comments about connecting the jumper cables to the audio cable made in the section on the Receiver Circuit, also apply here.

NOTE: YOU WILL NOT BE ABLE TO "SEE" WITH YOUR EYES IF THE LED IS EMITTING INFRARED LIGHT. Test the LED with the receiver circuit. If the LED does not work (you get no sound from the speaker when the LED is placed just above the photocell), switch the polarity of the battery (i. e. take the jumper cable connected to the positive terminal and connect it to the negative terminal, and vice versa).

TEACHING NOTES ON "LISTENING TO LIGHT"

Part I - The Photocell: *Students will use a detector to hear the presence of light.*

These demonstrations show students how the photocell detector can be used to "listen" to light. For the first demonstration, turn off the overhead fluorescent lights. Use a DC battery powered flashlight to shine on the surface of the photocell. Because the flashlight operates on DC current, there will be no fluctuations in the brightness of the light emitted and the speaker will be silent. The speaker only responds to *changes* in the voltage it receives, and a constant light source will cause the photocell to produce a constant voltage. However, if the teacher moves her or his hand back and forth to block the beam reaching the photocell, the speaker will emit a sound. The students should answer questions A-D while the teacher demonstrates the effects of the flashlight on the photocell detector. Question E should be answered before the teacher tests the students' predictions. Questions D and F allow the students to demonstrate an understanding that the photocell detector enables them to listen to *changes* in the brightness of light, not how bright the light is.

Part II - Your Own Music Station: *Students discover that information can be carried by visible and infrared light.*

These demonstrations show how information can be carried by both visible and infrared light. The first demonstration involves a laser beam aimed at the photocell surface from across the room.

SAFETY PRECAUTION: Be sure to caution students not to look into the laser beam.

Visible Light Demonstration

The laser should be aimed at the photocell surface before students answer Question A. Because the brightness of the laser light does not fluctuate, the speaker will emit no sound (although it may make a popping sound when the laser pointer is initially turned on, followed by no sound, or static, as the laser pointer continues to shine on it). It is up to the students to suggest that interrupting the light signal will produce a sound, and that this method might be used to send information along the laser beam (perhaps using Morse code). After the students have provided a method of communicating with their friend, the teacher can test their suggestions using the equipment.

Infrared Light Demonstration

When the teacher hits the photocell detector with the infrared signal from a remote control, the speaker makes a sound like a blaster gun from a science fiction movie. Different buttons on the remote produce signals with different fluctuations, but these changes are difficult to hear with the simple circuit used in the demonstration. If different brands of remote controls or different remote control devices are used, the sounds are easier to distinguish. Question B should be answered after the teacher demonstrates the response of the receiver to the remote control signal.

Before students answer Questions C, the teacher should demonstrate how the two circuits shown above are used to transmit and receive music via an IR signal. For best results, aim the top (not the side) of the LED directly at the photocell (so that the prongs on the LED point directly away from the photocell). To begin, hold the LED close to the photocell (within an inch or two). This ensures that students hear the music as loudly as possible at the beginning of the demonstration. Note that the music coming from the speaker will probably be rather quiet, even at its loudest. But it should still be easily heard, even if not loud.

The volume of the music will go down if the LED is moved farther away from the photocell surface. A simplified but appropriate explanation for this is that the light from the LED spreads out as it moves farther away. As a result of this spreading out, it appears "dimmer" the farther away it is. However, this is not the whole story. The sound produced in the speaker does not depend directly on the brightness of the light detected by the photocell, but rather on the changes in the brightness. As the LED moves farther away, and its light gets dimmer, the size of the brightness fluctuations detected by the photocell necessarily decreases. The smaller fluctuations in the light detected by the photocell result in smaller changes in the current sent to the speaker, and the resulting volume of the speaker is quieter.

Part III - What Gets Through? *Students investigate the infrared transmission properties of various everyday objects.*

The first demonstration uses a magnifying glass to focus the infrared light from the transmitter on the distant photocell. The LED and photocell should be placed about 1 meter apart with the LED still aimed toward the photocell. The signal will be so weak that no sound is heard. However, when a magnifying glass is placed between the LED and the photocell the sound becomes audible. The magnifying glass needs to be about 15 cm from the diode and should be moved back and forth to find the optimal location.

If students are not familiar with how a magnifying glass focuses visible light, this can be demonstrated using the flashlight. The fact that both visible light and infrared light are focused by the magnifying glass provides evidence that IR light does, in this instance, behave very much like visible light. *Note: Test the magnifying glass used prior to class. Different types of plastic and glass absorb IR emission, and you may find that your magnifying glass absorbs most of the IR from the LED.*

The activities associated with Question C & D demonstrate that many materials that are opaque to visible light are either totally or partially transparent to IR light.

Question E uses the observations from part III to help understand why astronomers are interested in using telescopes that view infrared light. Infrared light can indeed carry information in much the way that visible light can, but it can pass through interstellar dust, which is opaque to visible light. If you would like to show students images of astronomical objects taken in different wavelength ranges, see: http://www.ipac.caltech.edu/Outreach/Multiwave ("Objects at Multiple Wavelengths" are also included in section 5 of the "Image File" on the CD-ROM).
Note that objects at different temperatures emit light in different wavelength regions, with x-rays and gamma rays emitted by the hottest objects (millions and billions of degrees), and radio waves emitted by the coolest (tens of degrees above absolute zero). For example, an x-ray image of the Sun reveals gas in the outermost layers of the Sun at temperatures of millions of degrees, while a visible light image shows gas at much cooler temperatures (thousands of degrees) located deeper in the Sun.

MATERIALS NEEDED

NOTE: One set of these materials is required to teach this activity as a demonstration. Or, if sufficient materials are available, student can conduct the activities as a laboratory experiment in which case each group of students would require a set of materials.

Transmitter Circuit

- Infrared Light Emitting Diode (LED)*
- 0.22 μF (microfarad) Capacitor*
- Audio Cable with 1/8" mini-plug on one end*
- 5 Jumper Cables with alligator clips on both ends *
- AA Battery
- AA battery holder*

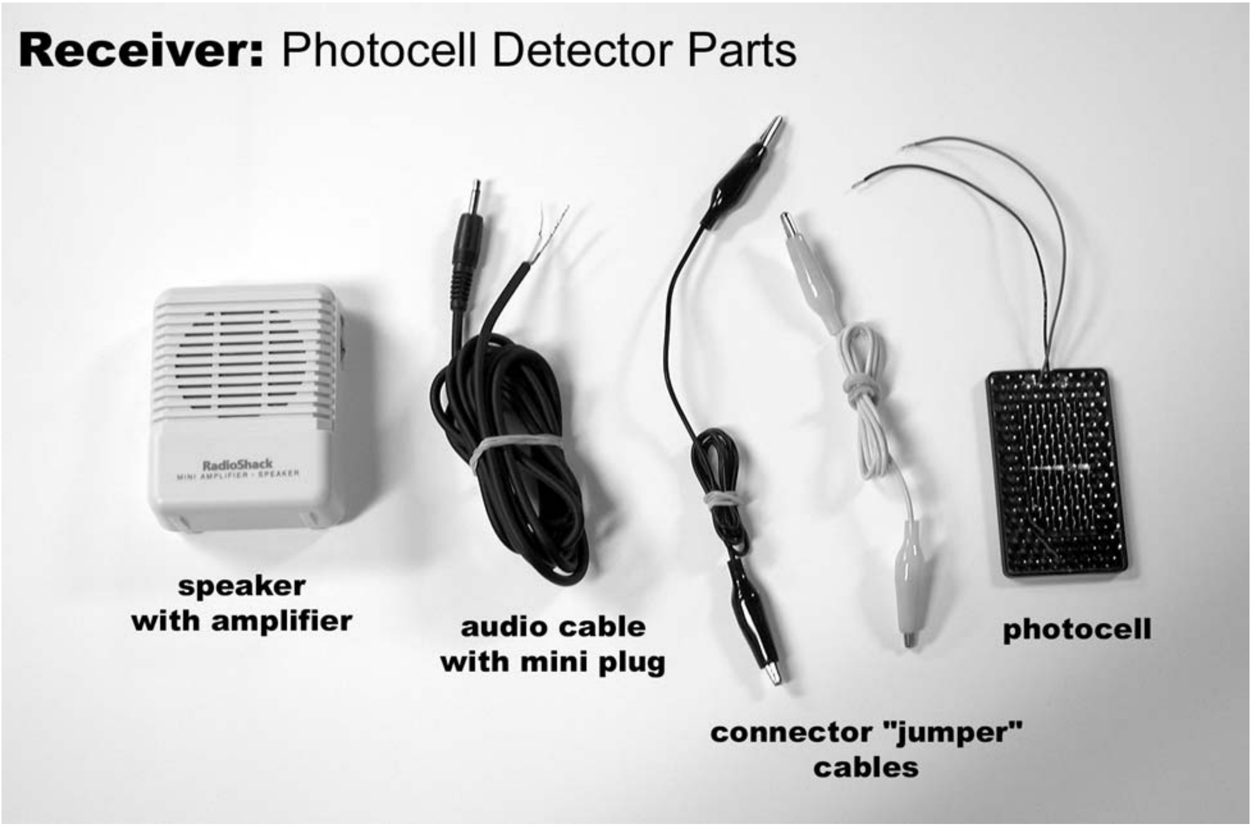
Receiver Circuit (Also used in "Sensing the Invisible")

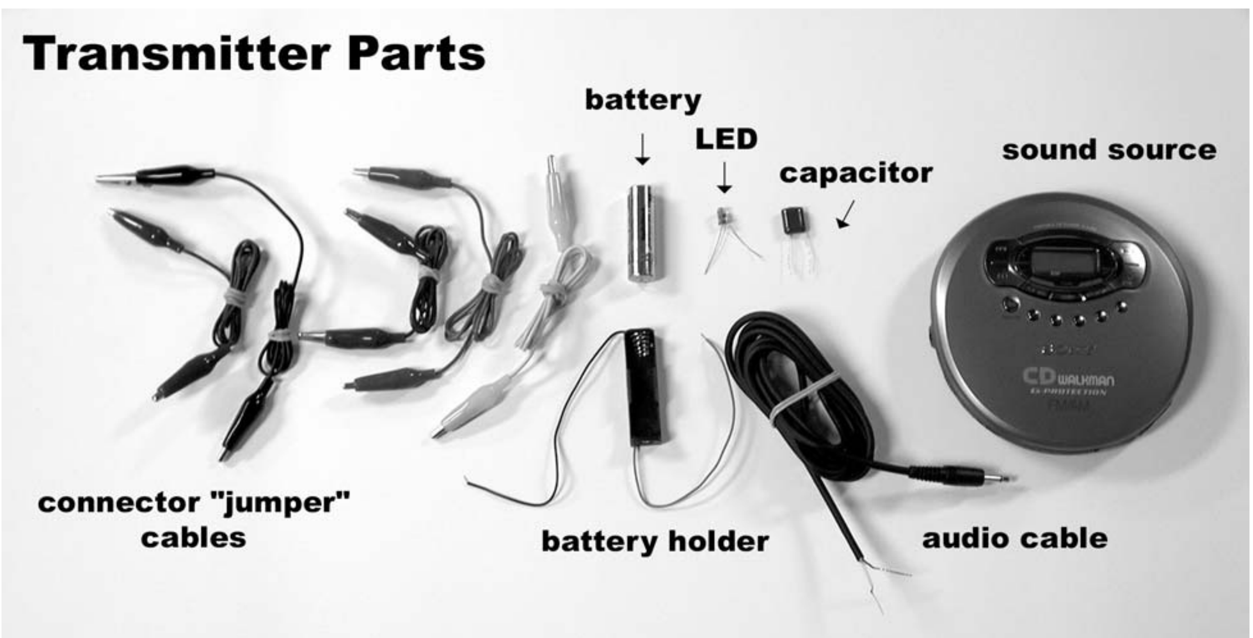
- Solar cell*
- Amplifier/Speaker*
- Audio Cable with 1/8" mini-plug on one end*
- 2 Jumper Cables with alligator clips on both ends*
- 9 Volt Battery for Amplifier/Speaker

Other Materials Required

- Audio source (CD Player, Walkman, or Transistor radio)
- Large magnifying glass of focal length around 15cm *(fairly standard)
- Flashlight
- Laser pointer (or other laser device)
- Collection of remote control devices from several different manufacturers
- Clear plastic bag
- Colored plastic bag
- Tissue
- Piece of paper
- Piece of cardboard
- Phillips screw driver

*see section 1.5 for details


Receiver: Photocell Detector Parts
RadioShack
MINI AMPLIFIER · SPEAKER
speaker
with amplifier
audio cable
with mini plug
connector "jumper"
cables
photocell


Transmitter Parts
battery
LED
capacitor
sound source
CD WALKMAN
connector "jumper"
cables
battery holder
audio cable

5.2 PART I — THE PHOTOCELL

Name___________________________________ Date___________ Period__________

In this activity we use a detector (a photocell connected to a speaker) to "listen" to light. Our detector is capable of detecting light in both the visible and infrared parts of the electromagnetic spectrum.

Experiment	Results
A. Describe what you hear from the speaker when your teacher shines a flashlight on the photocell detector.	
B. Do you hear any difference as your teacher moves the flashlight closer and farther away from the photocell to make the light dimmer and brighter?	
C. Describe what you hear when your teacher moves her or his hand back and forth between the flashlight and the photocell.	

D. Does the sound from the photocell detector result from the brightness of the light or from changes in the brightness of the light? What is your evidence?

	Prediction	Observation
E. What will you hear when the photocell detector is exposed to light from the fluorescent overhead lights?		

F. Is the light from a fluorescent bulb constant or does it change? Explain how you know.

PART II — YOUR OWN MUSIC STATION

Now we will explore how information can be carried by both visible and infrared light.

Experiment	Results
A. What happens when a laser beam shines on the photocell from across the room.	
Imagine that you had a similar apparatus set up between your house and your friend's house at the end of the block. How could you use this arrangement to send information to your friend?	

B. Describe what you hear when your teacher hits the photocell with the signal from a remote control.	
Is this information being transmitted using visible or invisible light?	
The small device in the end of the remote control that produces the infrared light is called an infrared diode. Is the "brightness" of the light from the infrared diode constant or does it flicker? How do you know?	

When the brightness of an infrared diode is changed using the output from an audio source, such as a CD player, the information in the music can be transmitted to a photocell and on to a speaker.

C. Explain carefully, possibly with a picture, why the volume of the music goes down as the infrared diode is moved farther away from the photocell.

PART III — WHAT GETS THROUGH?

In this part we will we look at how infrared light is similar to visible light and how it is different.

Experiment	Result
A. What happens when the transmitter (infrared diode) is placed about 1 meter from the receiver?	
B. What happens when your teacher uses a magnifying glass to focus the IR light from the transmitter?	

C. Predict (circle) what will happen to the volume of the music when each of the objects listed is placed between the diode and the photocell. Then record your observations after your teacher performs each experiment.

1. A hand:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

2. A clear plastic bag:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

3. A colored plastic bag:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

4. A tissue:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

5. A piece of paper:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

6. A piece of cardboard:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

D. When your teacher performed each of the experiments, were any of the results surprising? Which ones?

E. Space is not as empty as we often think it is. Much of space is filled with gas and dust that astronomers call the interstellar medium. This dust can block visible light from distant objects making them impossible to see. Why did the development of infrared telescopes allow astronomers to “see” these previously unseen objects?

5.3 PART I — THE PHOTOCELL

Name__________________________________ Date___________ Period__________

In this activity we use a detector (a photocell connected to a speaker) to "listen" to light. Our detector is capable of detecting light in both the visible and infrared parts of the electromagnetic spectrum.

Experiment	Results
A. Describe what you hear from the speaker when your teacher shines a flashlight on the photocell detector.	*Initial "pop" when light from the flashlight hits, then nothing (but static) while the light continues to shine on the photocell.*
B. Do you hear any difference as your teacher moves the flashlight closer and farther away from the photocell to make the light dimmer and brighter?	*No. There may be an increase in static as the flashlight is moved farther away.*
C. Describe what you hear when your teacher moves her or his hand back and forth between the flashlight and the photocell.	*Popping sound every time the light hits the photocell.*

D. Does the sound from the photocell detector result from the brightness of the light or from changes in the brightness of the light? What is your evidence?

The photocell detects changes in the brightness of the light. There was no sound when the flashlight was close to the photocell (bright), and still no sound when it was farther away (dim). So the brightness of the light can't be what's detected. When the light is interrupted or changed rapidly (when the hand was moved back and forth between the flashlight and the photocell), there was a popping sound. This change in brightness was what was detected by the photocell and sent to the speaker.

	Prediction	Observation
E. What you will hear when the photocell detector is exposed to light from the fluorescent overhead lights?	*Answers will vary.*	*Fluorescent lights cause a constant hum at a specific pitch.*

F. Is the light from a fluorescent bulb constant or does it change? Explain how you know.

The light from a fluorescent bulb changes. Because the photocell only detects light that's changing, the constant hum produced in the speaker by the photocell proves the light is constantly changing.

PART II — YOUR OWN MUSIC STATION

Now we will explore how information can be carried by both visible and infrared light.

Experiment	Results
A. What happens when a laser beam shines on the photocell from across the room.	*Not much. There may be an initial pop when the laser first hits the photocell, but then nothing (but static) while the laser continues to shine on the photocell.*
Imagine that you had a similar apparatus set up between your house and your friend's house at the end of the block. How could you use this arrangement to send information to your friend?	*You would have to have some way to interrupt or rapidly change the brightness of the laser beam, so that it flashed in something like Morse Code.*

B. Describe what you hear when your teacher hits the photocell with the signal from a remote control.	*Sound like a blaster gun from a science fiction movie; the sound continues to fluctuate rapidly as long as the button is pressed.*
Is this information being transmitted using visible or invisible light?	*Infrared light.*
The small device in the end of the remote control that produces the infrared light is called an infrared diode. Is the "brightness" of the light from the infrared diode constant or does it flicker? How do you know?	*The brightness of light from the infrared diode must flicker because sound was heard from the speaker and that only happens when the brightness of light that strikes the photocell is changing.*

When the brightness of an infrared diode is changed using the output from an audio source, such as a CD player, the information (music) can be transmitted to a photocell and on to a speaker.

C. Explain carefully, possibly with a picture, why the volume of the music goes down as the infrared diode is moved farther away from the photocell.

As the infrared diode is moved farther away, the light it emits gets spread out over a larger area and, therefore, appears dimmer. Thus the changes in the light that the photocell detects are smaller and the signal sent to the speaker is smaller and the volume goes down.

PART III — WHAT GETS THROUGH?

In this part we will we look at how infrared light is similar to visible light and how it is different.

Experiment	Result
A. What happens when the transmitter (infrared diode) is placed about 1 meter from the receiver?	*The music should not be able to be heard because the signal from the distant infrared diode is too weak to be detected by the photocell.*
B. What happens when your teacher uses a magnifying glass to focus the IR light from the transmitter?	*You can hear the music again, although it may be faint. The magnifying glass focused the infrared light, just like it does visible light, increasing the brightness of the infrared signal enough to be detected again.*

C. Predict (circle) what will happen to the volume of the music when each of the objects listed is placed between the diode and the photocell. Then record your observations after your teacher performs each experiment.

1. A hand:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

2. A clear plastic bag:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

3. A colored plastic bag:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

4. A tissue:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent

5. A piece of paper:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent
   Which result you get depends on the thickness of the paper.

6. A piece of cardboard:
   Prediction: stay the same get slightly quieter get a lot quieter become silent
   Observation: stay the same get slightly quieter get a lot quieter become silent
   Which result you get depends on the thickness of the cardboard.

D. When your teacher performed each of the experiments, were any of the results surprising? Which ones?

Answers will vary, but students may express surprise that objects that block visible light let some or all of the infrared light pass through them, e.g., the colored plastic bag, the paper, and the cardboard.

E. Space is not as empty as we often think it is. Much of space is filled with gas and dust astronomers call the interstellar medium. This dust can block visible light from distant objects making them impossible to see. Why did the development of infrared telescopes allow astronomers to "see" these previously unseen objects?

Like the colored plastic bag, the paper, or the cardboard, interstellar dust blocks visible light but lets infrared light pass through it. Any objects located behind the dust and emitting visible light cannot be seen. Astronomers using telescopes that can detect infrared light can "see" through the dust to the objects emitting the infrared light, just as the photocell could "see" the brightness changes from the infrared diode (produced by the music) through the colored plastic bag, paper and cardboard.